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A STUDY OF THE UTILIZATION OF PENTOSANS BY CERTAIN ANIMALS

by

WILLIAM ABBOTT BRANNON

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A STUDY OF THE UTILIZATION OF PENTOSANS BY CERTAIN ANIMALS.

The pentosans, on account of their carbohydrate nature and the large percent of the nitrogen free extract which they make up in roughage feeding stuffs have for some time been the subject of investigations, notably by Tollens and Flint, Salkowski, Neuberg and Wohlgemuth abroad, and in this country by Lindsey, Stone and Fraps. Investigations seem to have shown that these sugars, or anhydrides as they occur naturally, are of nutritive value to herbivorous animals.

Salkowski (1) in six of seven experiments with rabbits when feeding l-arabinose was able to demonstrate a glycogen formation in the liver of from 0.595--2.06 grams. This glycogen was the usual one, and not, as he had expected, a glycogen with five carbon atoms. It also showed no trace of pentose sugars by spectrum analysis.

These results are substantiated by Cremers (2) who found that l-arabinose, xylose and the methyl pentoses when fed to rabbits and hens had a positive influence on glycogen formation. These results have however been questioned by Frenzel (2) who freed a rabbit's liver of glycogen by strychnine poisoning at the beginning of his experiments. His observations led him to conclude that xylose did not cause glycogen formation in rabbits, either directly or indirectly.

The possibility that the configuration of the pentose sugar fed might have an influence on its availability to animal organism was investigated by Neuberg and Wohlgemuth (3) The three optical isomers of arabinose were fed separately to the same animal, except when the animal was killed to investigate the glycogen content of its liver. According to the data obtained there was considerable difference in the degree to which they were utilized. Of l-arabinose, when fed directly (per os) 85.5% was utilized; of d-arabinose 68.8%; and of racemic arabinose 71.5%. Injected subcutaneously 92.9% of l-arabinose appeared to be utilized; 64% of d-arabinose, and 68.3% of r-arabinose. On direct injection into the circulation through the ear-vein l-arabinose was utilized to 71.7%, d-arabinose to 69%, and r-arabinose to 71%. The lower utilization of l-arabinose in the last case was attributed to its escaping the action of the digestive juices by this method of administration. By utilization is meant the percent of pentoses found in the animal's urine subtracted from 100. The same relative digestibility seemed to hold also for the three arabite alcohols. In feeding r-arabinose a part of it was in all cases decomposed into l- and d-arabinose, the laevo-form on account of its apparantly easier destructability, appearing in less amounts in the urine than the d-arabinose. Since the ferments, especially zymase, appear to be without

action on r-arabinose, it would seem that the physiological activities of the body were able to affect this pentose to a remarkable extent. Only traces of glycogen formation were found on feeding d- and r-arabinose, whereas considerable quantities were found when l-arabinose was fed.

It would seem from Slotzoff's experiments (4) that the pentosans do not need to be hydrolysed in order to enter the circulation from the digestive tract. Slotzoff's experiment consisted in feeding pure xylan, obtained by Salkowski's method (4), to rabbits, and an estimation of the pentosans in feces and urine to obtain a factor of digestibility. He obtained an average factor of 55.78%. On investigations of the organs and tissues of the animal, he found xylan in the liver and muscles. From extracts made from the muscles he was twice able to obtain a typical copper-xylan precipitate,-indicating that this pentosan had not undergone hydrolysis in the digestive tract. In the urine Slotzoff found from 1.49 to 4.63 % of xylan, and as he could produce no osazone from it, concluded that it appeared in the urine as soluble xylan.

In this experiment from sixteen trials Slotzoff was not once able to find any action on xylan by ptyalin, or pancreatic juice. Gastric juice acted gradually on xylan, but as the same action was demonstrable in a control experiment

where the juice had been previously heated, this gradual solubility in gastric juice seemed to be due entirely to the HCl present.

0.25-5 grams of xylan kept in a putrifying medium composed of 100 grams of finely chopped meat, one liter of tap-water, and ten cubic centimeters of saturated sodium carbonate, showed a pentosan reaction even after six to seven days, and this reaction did not dissappear until the ninth day. As food would not ordinarily remain in the digestive tract nearly so long as this, Slotzoff concluded that putrifaction processes would not account for the disappearance of 55.78% of the xylan fed to the rabbit.

The pentoses are much more readily attacked by putrifactive bacteria than the pentosans. This appears from Salkowski's experiments (5) with l-arabinose and xylose. On subjecting these sugars to the same putrifactive medium as that used by Slotzoff, he found the pentose reaction disappearing after four days.

Researches on the decomposition products of these sugars after undergoing this fermentation showed the presence of fatty acids, acetic acid in considerable amounts, and also succinic acid. In two experiments Salkowski was able to demonstrate alcohol as a decomposition product of l-arabinose, whereas xylose gave no more alcohol on distilla-

tion than the control experiment. As three other experiments with l-arabinose failed to give any alcohol this alcohol production was left uncertain. Salkowski concluded that l-arabinose will undergo alcoholic fermentation with certain organisms. As regards xylose he was unable to say, since his negative results with this sugar might have been due to the absence of the proper bacterial flora.

An experiment by Bendix (5) on xylose, arabinose, and Rharmnose for fermentation products where bacteria from animal feces were used, showed the bacteria to be active when the mixture contained pancreas-powder, ovary-powder, or peptone. According to his results fermentation proceeded easiest with xylose, less easily with Rharmnose, and poorest with arabinose. The products of fermentation were: volatile fatty acids, alcohol, and lactic acids. The gases produced were carbon dioxide and oxygen.

A few experiments have been carried out where the pentosans fed were not pure substances, but a mixture of pentosans as they occured naturally in the feeding stuffs used. Stone (6) carried on a digestibility experiment with rabbits in which he fed a mixture of wheat bran and corn meal. One rabbit digested 58.93% of the pentosans in the feed given, the other 62.40%. In a second experiment (6) in which only wheat bran was fed, the digestion amounted

to only 38.31% of the pentosan content of the feed.

Stone (6) also determined the relation of the pentosans to the nitrogen free extract of the feed and of the feces. He found that the proportion in the feces was much higher than in the feed, showing that the pentosans are less attacked than the other constituents of the nitrogen free extract. When wheat bran alone was fed, and the protein content of the feed increased over a ration of wheat bran and corn meal, the digestibility of pentosans decreased from 60 to 40 per cent.

A similar experiment by Stone and Jones (2) of feeding pentosans in raw feeds to sheep showed a digestibility varying from 44 to 71 percent. In this case Stone's method for pentosan estimation was used: that is, furfurol distilled was titrated with phenylhydrazin, Fehling's solution being used as an indicator.

Weiske (2) also experimented along this line. The rations he used consisted of wheat straw and oats, and the animals used were wethers. He found wheat straw, moisture free, to contain 27.64% pentosans, and oats 15.55% by the Tollens and Flint method which is a precipitation of the furfural with phenylhydrazin. His animals digested from 62.2 to 66.8 per cent of the pentosans present.

Weiske also found that it seemed to make no difference

in the digestibility of the pentosans whether the animal drank before or after consuming its feed.

In a second experiment (2) Weiske fed two rabbits 80 grams of oats per day. A variation was tried in that the feed was dried at 100 degrees centigrade for some time in one period of the experiment. The rabbits appeared to digest a small amount more of the pentosans when the feed was dry than when it was only air-dry. He obtained in this experiment an average digestibility of 53.81%. From his data he concluded that the pentosans of wheat straw are somewhat more digestible than are those of oats.

In the United States, besides the work of Stone, Lindsey of the Massachusetts Experiment station has studied on the digestibility of various feeds and the grasses. Fraps (8) of the North Carolina Experiment station has also done considerable work on the furfural distillation products, and the pentosans as they occur naturally.

The literature on pentosans does not show, however, any work to have been done on pentosan digestibility by cattle. As among the herbivora, cattle are among the largest consumers of pentosans, and since various factors such as structure of the digestive tract and possible variation in the bacterial flora characteristic of different species would probably have an important bearing on this

subject it has seemed worth while to carry on a digestibility experiment of this kind with cattle.

An experiment has been in progress at the Wisconsin Experiment station for some time, in which calves have been fed on rations derived entirely from a single plant source. One lot received a ration consisting of corn meal, corn gluten feed, and corn stover; another a ration consisting of ground wheat, wheat gluten, and wheat straw; and a third a ration made of rolled oats and oat straw. Since these animals had been long accustomed to a particular class of foods it was thought to offer an excellent opportunity to study the degree of utilization of the pentosans supplied by the above mentioned plants.

Quantitative collections of the feces and urine of the animals were made for 24 hour periods continuously for seven days. The excreta were weighed and sampled carefully and samples preserved for analysis. A five pound sample of the feces was dried at 65 degrees centigrade, in a current of air, the sample being spread out in a thin layer. After drying, the samples were placed in paper sacks and preserved until they had acquired an air-dry moisture content, when all samples were weighed at the same time and further sampled and ground for analysis. The urine was preserved with chloroform and toluol in sealed mason jars.

Pentoses were estimated according to the official

method: a distillation with 12% hydrochloric acid, and precipitation of the resulting furfural by phloroglucin solution. The precipitate was allowed to collect and settle over night, then filtered into a weighed gooch crucible, washed with 150 cc. of water, dried four to six hours, and weighed. Pentoses were calculated from the formulas given in the official methods. The feces were analysed in the same way for pentoses. The amount of pentoses present in the urine was found to be so small that it could be left out of account. See table I.

Tables showing the content of Furfurol yielding substances in the calves' urine, calculated as pentoses.

TABLE I.

Date	Plant supplying ration	No. of Calf	Vol, of day's Urine	Pentose content of urine (gms)
Feb. 14, 1909	Mixture { Oat Wheat Corn	555	4907 cc.	1.1237
Feb. 15, 1909	Mixture { Oat Wheat Corn	563	4509 cc.	1.2895
Feb. 1, 1909	Oat	567	4564 cc.	1.7571
Feb. 1, 1909	Oat	569	6999 cc.	2.4486
Jan. 21, 1909	Corn	572	2650 cc.	0.8222
Jan. 21, 1909	Corn	558	3219 cc.	1.2647
Jan. 10, 1909	Wheat	565	2848 cc.	1.2106
Jan. 10, 1909	Wheat	571	2627 cc.	0.9050

TABLE I (con)

Date	Plant supplying ration	No. of Calf	Vol. of day's Urine	Pentose content of urine (gms)
Mar. 18, 1908	Corn	572	3016 cc.	1.3059
Mar. 20, 1908	Oat	569	2979 cc.	1.8291
Mar. 15, 1908	Wheat	565	5732 cc.	3.2400

This small content of pentoses in the urine of herbivorous animals has been already found to be true by Weiske and Lindsey, and argues for an actual utilization of pentosans by them. Since substances other than pentoses, especially glycuronic acid, normally found in urine, yield furfurol on distillation, it is questionable whether any pentoses were present in these urines.

Methyl pentosans were also estimates by Tollen's and Ellett's method which is a repeated extraction of the phloroglucid precipitate with 95% alcohol at 65 degrees centigrade, until the color of the alcohol shows that no more methyl-furfural-phlorogucid, which substance is soluble in 95% alcohol, is being dissolved out of the precipitate. Tollens and Ellett have shown that this extraction effects a nearly complete separation where small amounts of substance have been used in the original precipitation. Their formula for calculation of Rhamnose is: Rhamnose = Ph 1.65 -

Ph^2 1.84 + .01, in which Ph is the weight of methyl-furfural phloroglucid found to be soluble in 95% alcohol. This weight is arrived at by drying the extracted precipitate, reweighing, and subtracting from the weight first obtained for the total precipitate.

Disappearance of the Pentosans of the Corn Plant from the Digestive Tract of the Cow.

The disappearance of the pentosans contained in the corn ration were first studied.

Table showing the rations used.

TABLE II

Ration	Percent of Pentoses (air dry)	Weight of Pentoses (grams) Mositure free
5 lbs. corn meal	12.02%	272.61
7 lbs. corn stover	28.86%	916.37
2 lbs. gluten feed (corn)	18.52%	168.04
		1357.02 total

Since the fourteen pounds of feed were entirely consumed the animals obtained daily 1357.02 grams of pentoses calculated on a moisture free basis. This amount represents total pentoses and includes methyl pentoses. A separate estimation of the dissappearance of methyl pentoses calculated as Rhamnose was made later.

Table showing the disappearance of pentoses of the corn ration for the corn fed calf for the year 1908.

TABLE III

Date	Amt. feed given per day (lbs)	Contained of pentoses calc. on moisture free basis (gms)	Weight of feces per day calc, to moisture free basis (gms)	Pentoses in dry feces (gms)	% Pentoses disappearing from digestive tract
Feb. 14	14	1357.02	817.7	189.6	86.03
Feb. 15	14	1357.02	1687.4	401.3	70.45
Feb. 16	14	1357.02	1999.2	522.4	61.50
Feb. 17	14	1357.02	1566.8	352.8	74.00
Feb. 18	14	1357.02	1767.1	440.5	67.55
Feb. 19	14	1357.02	1948.8	490.9	63.83
Feb. 20	14	1357.02	1899.2	378.1	72.14
Feb. 21	14	1357.02	1893.1	395.5	70.85
				Average	70.79

The disappearance of the pentoses was obtained by subtracting the percentages found to be not utilized from 100% As before mentioned no account was taken of the pentoses in the urine as they did not exceed 0.2% on the average and could be safely disregarded. In order to substantiate this work further to see if a longer period of feeding would influence the disappearance of pentoses, the work was repeated on the same animal one year later, January 1909.

Table showing disappearance of pentosans of corn plant in the experiment of the year 1909.

TABLE IV

All analyses calculated as pentoses.

Date	Intake (gms per day) Pentoses	Weight of feces (air dry) gms.	% Total Pentoses in feces.	Weight Pentoses in feces	% disappeared from digestive tract
Jan. 18	1550.4	2085.0	18.13	378.01	75.62
Jan. 19	1550.4	2328.8	22.36	520.5	66.43
Jan. 20	1550.4	2097.9	22.32	468.2	69.81
Jan. 21	1550.4	2042.0	22.10	451.2	70.90
Jan. 22	1550.4	1899.5	24.44	464.1	70.07
Jan. 23	1550.4	2058.2	22.68	466.7	69.90
Jan. 24	1550.4	2062.0	22.36	461.0	70.27
				Average %	70.43

Results are not calculated to moisture free basis in this table. The percentage of disappearance of pentoses in 1908 and 1909 is almost the same. Account was also taken of the methyl pentoses calculated to Rhamnose and a separate table constructed to show the percent to which they disappeared from the digestive tract. On account of lack of time only three analyses were made on the air-dry feeds and feces.

Disappearance of Rhamnose of the corn plant in Experiment of the year 1908.

TABLE V

Date	Amt. of feed per day	Amt. of feces. (air dry) (gms)	Rhamnose in air dry feed (gms)	% Rhamnoses in feces (gms)	% disappeared from digestive tract.
Feb. 14	14 lbs	2833.4	216.5	4.31%	45.95%
Feb. 20	14 lbs	2667.6	216.5	3.08%	61.17%
Feb. 21	14 lbs	2732.6	216.5	3.08%	62.00%
				Average	56.37%

Table showing disappearance of Rhamnose of the corn plant from digestive tract of the cow in experiment of the year 1909.

TABLE VI

Date	Amt. of feed per day	Amt. of feces. (air dry) (gms)	Rhamnose in air dry feed (gms)	Rhamnoses in feces (gms)	% disappeared from digestive tract.
Jan. 18	16 lbs	2985.0	247.4	56.08	77.32
Jan. 19	16 lbs	2328.8	247.4	55.63	77.51
Jan. 20	16 lbs	2097.9	247.4	57.90	76.60
Jan. 21	16 lbs	2042.0	247.4	75.14	69.63
Jan. 22	16 lbs	1899.5	247.4	30.44	87.62
Jan. 23	16 lbs	2058.2	247.4	43.01	82.62
Jan. 24	16 lbs	2062.0	247.4	57.32	76.83
				Average	78.30

Dissappearance of the Pentosans of the Wheat Plant from the Digestive Tract of the Cow.

Table showing rations used:

TABLE VII

Ration	Percent of Pentoses	Weight of Pentoses (grams) (moisture free)
7 lbs. wheat straw	23.09%	733.24
6.7 lbs. whole wheat	11.73%	356.52
0.3 lbs. wheat gluten	1.33%	18.06
		1107.82 total

1107.8 grams pentoses calculated on moisture free basis were consumed by the wheat-fed calf daily.

Table showing disappearance of pentoses of wheat ration from the digestive tract of calf, year 1908.

TABLE VIII

of pentoses than was found for 1908.)

Table showing the disappearance of pentosans from the digestive tract of cow in the experiment of the year 1909.

TABLE IX

All analyses calculated as pentoses.

Date	Intake Pentoses (gms per day) (air dry)	Weight of feces (air dry) gms per day.	% total Pentoses in air dry feces.	Wt. of Pentoses in feces (gms)	Pentoses disappearing from digestive tract, (%)
Jan. 10	1251.5	2700.8	25.42	686.3	45.19
Jan. 11	1251.5	2783.0	24.54	682.9	45.44
Jan. 12	1251.5	2364.7	25.99	614.5	50.90
Jan. 13	1251.5	2992.8	25.26	756.0	39.60
Jan. 14	1251.5	2512.5	25.04	629.0	49.75
				Average	46.18

*

Table showing disappearance of Rhamnose in the experiment of the year 1908 (wheat rations)

TABLE X

Date	Amt. of feed per day.	Amt. of feces (air dry) (gms)	Rhamnose in air dry feed (gms)	Rhamnose in feces (air dry) (gms)	Disappearance of Rhamnose from digestive tract.
Feb. 24	14 lbs	2887.0	207	31.99	60.39%
Feb. 26	14 lbs.	2743.3	207	44.99	78.27%
Feb. 29	14 lbs	2858.8	207	44.88	78.32%
				Average	72.33%

* (The analysis for the year 1909 shows less disappearance of pentoses than was found for 1908.)

Table showing disappearance of Rhamnose of wheat rations in the experiment of the year 1909.

TABLE XI

Date	Amt. of feed per day.	Amt. of feces (air dry) (gms)	Rhamnose in air dry feed (gms)	Rhamnose in feces (air dry) (gms)	Disappearance of Rhamnose from digestive tract.
Jan. 11	16 lbs	2783.0	238.7	0.0	100.0%
Jan. 12	16 lbs	2364.7	238.7	0.0	100.0%
Jan. 13	16 lbs	2992.8	238.7	93.37	60.81%
Jan. 14	16 lbs	2512.5	238.7	75.87	68.13%
				Average	82.23%

Disappearance of the Pentosans of the Oat Plant from the Digestive tract of the Cow.

Table showing oat rations used:

TABLE XII

Ration	Per cent of Pentoses	Weight of Pentoses (grams) (moisture free)
7 lbs. oat straw	27.99	879.9
7 lbs. oat meal	7.07	203.9
		1083.8 total

Table showing disappearance of total pentoses of Oat ration in the experiment of the year 1908.

TABLE XIII

Date	Amt. feed given per day (lbs)	Contained of pentoses calc on moisture free basis (gms)	Weight of feces per day calc, to moisture free basis (gms)	Pentoses in dry feces (gms)	Disappearance of Pentoses from digestive tract.
Mar. 2	14	1083.8	1875.7	423.6	60.91
Mar. 3	14	1083.8	2591.9	585.5	45.96
Mar. 4	14	1083.8	2240.3	508.6	53.07
Mar. 5	14	1083.8	2265.7	529.9	51.11
Mar. 6	14	1083.8	2591.6	533.3	50.79
Mar. 7	14	1083.8	2084.7	454.9	58.02
Mar. 8	14	1083.8	1951.0	463.4	57.24
				Average	53.87

Table showing disappearance of total pentoses of Oat ration in the experiment of the year 1909.

Table showing disappearance of Rhamnose of Oat ration in the experiment of the year 1908.

TABLE XV

Date	Amt. of feed per day.	Amt. of feces (air dry) (gms)	Rhamnose in air dry feed (gms)	Rhamnose in feces (air dry) (gms)	Disappearance of Rhamnose from digestive tract.
Mar. 2	14 lbs	2463.9	147.3	57.66	60.85
Mar. 3	14 lbs	3435.4	147.3	57.01	61.29
Mar. 6	14 lbs	3285.7	147.3	62.10	57.84
Mar. 7	14 lbs	2872.9	147.3	62.23	57.25
				Average	59.31

Table showing disappearance of Rhamnose of Oat ration in the experiment of the year 1909.

TABLE XVI

Date	Amt. of feed per day.	Amt. of feces (air dry) (gma)	Rhamnose in air dry feed (gms)	Rhamnose in feces (air dry) (gms)	Dissappearance of Rhamnose from digestive tract.
Jan. 26	14 lbs	2497.1	152.18	86.05	43.1%
Jan. 27	14 lbs	1907.6	152.18	44.43	70.81%
Jan. 28	14 lbs	2587.9	152.18	65.42	57.00%
Jan. 29	14 lbs	2197.3	152.18	54.09	64.46%
Jan. 30	14 lbs	2017.0	152.18	45.66	70.00%
				Average	61.05%

As far as could be ascertained no estimate of the disappearance of pentosans from digestive tract of pigs had been made. An experiment of this kind was accordingly carried out with two pigs. The two pigs used in this experiment weighed about 100 pounds each. They had been used in another experiment in which their phosphorous metabolism was studied and the rations differed in one respect, viz. in the amount of phosphorous they contained. The pig designated as No. 1 is the same as that designated as "Basal Pig" in the report of the above experiment. (See American Journal of Physiology, Vol. XXIII p. 271, 1909 edition) The phosphorous content of its ration had been maintained at a very low level during a period of four months after weaning and as a result the animal was in a debilitated condition. Whether the higher degree of disappearance of pentosans in this experiment is to be attributed to a longer retention of the food residues by the animal cannot be decided with certainty.

Pid No. II was one of the lot designated "floats lot" #509 in the experiment above referred to. It was a vigorous pig, receiving its supply of phosphorous mainly from "floats" or ground rock phosphate.

A number of analyses made on the urine of these pigs makes it again apparent that the anount of pentoses appearing in the urine constitutes an insignificant factor.

Table showing furfurol yielding substances in urine of pigs.

(Calculated as Pentoses)

No. of Pig.	Date	Vol. of Urine	Wt. of Pentoses in day's urine.
Pig II	Feb. 11	796 cc.	1.0089 gms.
Pig II	Feb. 12	1199 cc.	3.9768 gms.
Pig II	Feb. 13	679 cc.	2.3473 gms.
Pig I	Mar. 3	1009 cc.	0.1705 gms.
Pig I	Mar. 5	1009 cc.	0.3370 gms.
Pig I	Mar. 6	1019 cc.	0.1946 gms.
Pig I	Mar. 8	1100 cc.	0.2739 gms.

In this case methyl furfural phlorogucid soluble i
alcohol was subtracted from the total phloroglucid
cipitate and the disappearance of the classes of p
sugars separately estimated.

Ration fed to Pig No. I and Pig No. II.

TABLE XVII

Ration (gms) (air dry)	% Pentoses	Wt. Pentoses (air dry) (gms)	% of Rhamnose
Rice 861	1.02	8.78	1.63
Washed Wheat Bran 455.6	43.39	196.82	2.60
Wheat Gluten 113.4	0.73	0.83	2.11
Totals			

Table
from diges

Date Year 1908	W c i (
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appearing from the digestive tracts of rabbits.

The work of Omelianski (Centrabl f. Bateriologie, 2 abt. bd. 8 1902 S 193, and other papers in the same volume) has demonstrated that certain organisms from the digestive tract of herbivora (horse) cause the solution and disappearance of the most resistant celluloses in large quantities in artificial cultures. As is well known putrifactive processes are ordinarily far outweighed by fermentative processes in the digestive tract of this class of animals. It is to be expected that bacteria capable of utilizing cellulose or pentosans would not flourish in a medium consisting largely of meat, in which putrifactive products would accumulate in large quantities. Salkowski's experiment certainly does not represent the conditions existing in the digestive tract of a herbivorous animal.

In order to see what effect, if any, would be produced on the pentosan content by growing the bacteria found in the feces of cows with corn fodder, oat and wheat straw respectively in anaerobic culture the experiment of Omelianski has been repeated in the following manner: One gram of finely ground fodder or straw was weighed into an erlenmeyer flask. To this flask was then added 75 cc. of an infusion of fresh feces prepared by agitating 10 gms.

of the latter with 150 cc. of Omelianski's nutrient salt solution. After allowing the solid particles to settle the solution was decanted through muslin. Some pentoses were doubtless added with the solution, but the amount was not ascertained. The erlenmeyers were then connected in series by means of glass tubing passing through rubber stoppers and carbon dioxide passed through the series for one hour. A trap of mercury permitted the escape of gases formed by fermentation. The flasks were then incubated for fourteen days after which a furfural distillation was carried out on the contents of each flask. The results are given in the following table.

TABLE XX

Material used 1 gram.	Original content of 1 gm. in Pentoses.	After 14 days incubation with bacteria from calf feces.	Percent Pentoses disappearing.	
1. Corn fodder	0.2924 gm.	0.1435 gm.	14.89	15.04 av.
2. Corn fodder	0.2924 gm.	0.1405 gm.	15.19	
3. Wheat straw	0.2309 gm.	0.1655 gm.	6.54	6.49 av.
4. Wheat straw	0.2309 gm.	0.1666 gm.	6.43	
5. Oat straw	0.2799 gm.	0.1842 gm.	9.50	8.58 av.
6. Oat straw	0.2799 gm.	0.2033 gm.	7.65	

From these data it appears that micro-organisms present in the digestive tract of these cows will account in part for the disappearance of pentoses. By referring to the percentages of pentoses found to disappear from the digestive tract of these cows the following facts are evident: In the case of the corn-fed animal where there was an average disappearance of 70.61 percent we get a loss of pentoses from corn fodder through the agency of bacteria of 15.04 percent. In the case of the oat-fed animal 54.70 percent, and a loss from oat straw in artificial culture of bacteria from the digestive tract of 8.58 percent With the wheat-fed one, 50.87 percent average disappearance from the digestive tract, and a loss from the bacterial culture of 6.49 percent. Apparently there is a significant harmony in these results. The pentose. bodies of corn fodder are quite evidently more attracted by the bacteria than those of the oat straw, and these again more open to attack than those of wheat straw. Whether this difference is due to a distinctive set of organisms present in the digestive tract of each animal, or to a difference in the bacterial action cannot be decided from these data.

As a brief summary of these investigations the following facts may be pointed out.

1 Cattle will digest or cause to disappear from a

corn plant rations $\frac{70.79 + 70.43}{2} = 70.61$ percent of the pentose bodies present; from an oat plant ration $\frac{53.87 + 55.52}{2} = 54.70$ percent of the pentose bodies and from a wheat plant ration $\frac{55.55 + 46.18}{2} = 50.87$ percent

2. The pentoses furnished by an oat plant disappear in less amount from a cow's digestive tract than those of the corn plant; those of the wheat plant in less amount than those of the oat plant.

3. Pigs will cause a disappearance of pentose bodies from wheat bran of from 53 to 68 percent.

4. The methyl pentoses seem to disappear in both pig and cow digestion to a greater extent than other pentose bodies.

5. Pentose bodies are attacked by the bacterial flora of the cow's intestine, but not to an extent to explain the full percentage of disappearance obtained. Since, however, the incubation period of these organisms is not known, nor can they be expected to accomplish in artificial culture what they might in the intestine, it is not safe to conclude from these data that any other agency is active in the disappearance of pentosans from the digestive tract.

The well extablished fact of the production of fatty acids from pentosans by bacterial action would seem to indicate that in a secondary manner at least the pentosans doubtless have a nutritional value, since such bodies would

be absorbed and oxidized with heat production. Whether bacteria render pentosans soluble by converting them into pentoses through enzymic processes and thereby enable the animal to absorb a portion of these cannot be looked upon as established at present.

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